



*Institute of Paper Science and Technology
Atlanta, Georgia*

IPST Technical Paper Series Number 817

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August 1999

Submitted to
PaperAge

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SURFACTANT SPRAY: A NEW APPROACH TO FLOTATION DEINKING

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Flotation deinking is a common practice for removing ink from wastepaper, and it is becoming a key process in many recycling paper mills. The application of flotation was successfully introduced to the paper recycling industry in the 1980s, and its applications in wax removal, sticky control, and fiber fractionation have attracted great research interest. The chemistry of the flotation process has been reviewed. The deinking chemistry and the physicochemical interactions among air bubbles, fibers, and ink particles are very complex. Existing technologies and process designs of flotation deinking are based on experiences obtained from mineral flotation processes. Limited process control mechanisms are available. Many problems remain unsolved such as high fiber and water losses, fiber contamination by deinking chemicals, low efficiency in removal of small ink particles, etc. Therefore, innovative technologies based on the mechanistic understanding of flotation processes are greatly needed to solve or alleviate the above problems. Because of the significant variability in the supply of secondary fibers in recycling practices, process control in flotation deinking is very important to improve recycling operations.

Flotation deinking processes involve interactions among air bubbles, ink particles, and fibers. A successful flotation process typically has three major efficient subprocesses: detachment of the ink particles from waste fibers, effective adhesion of the ink particles onto air bubble surfaces, and removal of froth and ink particles from flotation cells.

In general, surfactants play three roles in flotation deinking: as a dispersant to separate the ink particles from the fiber surface and prevent the

red deposition of separated particles on fibers, as a collector to agglomerate small particles to large ones and change the surface of particles from hydrophilic to hydrophobic, and as a frother to generate a foam layer at the top of the flotation cell for ink removal. Although surfactants play important roles, they will also cause some adverse effects on ink removal, fiber quality, and water reuse. For example, both hydrophobicity and ink removal efficiency may decrease by the adsorption of dispersant and frother. The remaining surfactant in recycled fibers is another problem that may cause a decrease in fiber-fiber bonding, an increase in foams during the papermaking process, an adverse effect on printing, etc. Because surfactants have both positive and negative effects, it is of interest whether dispersant, collector, and frother can be separately controlled.

The surfactants used in mineral flotation may not be necessary in flotation deinking. For instance, some ink particles, such as xerox toner, are hydrophobic in nature and no collector is necessary. The dispersant may also be unnecessary if the ink particles can be removed from fibers by other chemicals, such as sodium silicate, sodium hydroxide and enzyme, or by mechanical actions, such as magnetic and electrical fields, and ultrasonic irradiation. Although a dispersant and a collector may not be necessary for some pulps, a frother has to be used in order to obtain a stable foam layer for removing ink particles. Traditionally, the frother and other surfactants are mixed with pulp slurry. However, the surfactant presented in pulp slurry will not only contribute to the foam stabilization, but also adsorb onto ink particle surfaces and in most cases, it causes a decrease in the hydrophobicity of ink particles. Furthermore, the mechanical control of froth stability is very difficult if the surfactant is directly added into the pulp slurry because the properties of wastepaper may vary significantly.

Because the foams are stabilized by surfactant only on the top of the flotation cell, it is advantageous to develop a feasible method to directly add the frother to the top of the flotation cell rather than in the pulp suspension. As a

result, separate control of the addition of various surfactants to improve the performance of deinking processes can be achieved.

An innovative approach called surfactant spray was developed at IPST. This innovative approach uses one simple mechanical device, i.e., surfactant spray at the top of the flotation column to control several key process variables, i.e., surfactant consumption, concentration and its distribution, froth structure and stability, and fluid dynamics in the froth. Therefore, surfactant (frother) is not directly added into the pulp suspension during stock preparation, rather, it is delivered through a spray during the flotation process.

The mechanism of surfactant spray is easily understood. Figure 1 illustrates that the ink particle adheres to an air bubble and moves to the liquid surface in a conventional flotation cell. The surfactant molecules presented in the bulk solution adsorb onto the bubble and ink surfaces and stabilize the bubble in a foam layer. Figure 2 illustrates that the ink particle could also adhere to an air bubble in the absence of surfactants if the ink particle is originally hydrophobic, such as a copy toner particle. The ink particle moves with the air bubble up to the surface of liquid. Because there is no surfactant in this system, the bubble breaks at the surface and the ink particle returns to the bulk phase. Figure 3 illustrates that the ink particle adheres to an air bubble in the absence of surfactant in the bulk phase. When the bubble and ink move to the surfactant layer that is generated by sprayed surfactant, the surfactant molecules adsorb onto the bubble and ink particle surfaces. As a result, the bubble is stabilized and a foam layer is generated, similar to that in a conventional flotation process. It is clear that, under this ideal condition, the following advantages can be achieved using the surfactant spray approach:

1. Hydrophobicity will not decrease because there is no adsorption of surfactant on ink particles and air bubbles before they reach the surface.
2. Fiber will not be contaminated by surfactant because surfactant does not come in contact with fibers in the bulk phase.

3. Surfactant consumption can be significantly reduced because only a thin layer of surfactant is needed.
4. Foaming ability and stability can be controlled by sprayed surfactant.

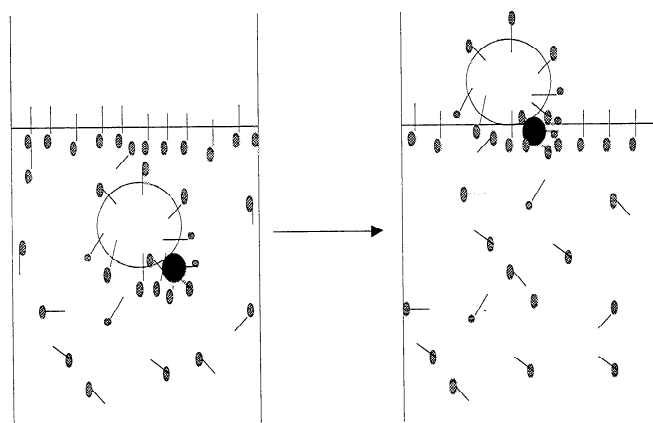


Figure 1. Ink-bubble interaction in a conventional flotation deinking process. The ink particles can be transferred to the foam layer if multiple bubbles are present in the system.

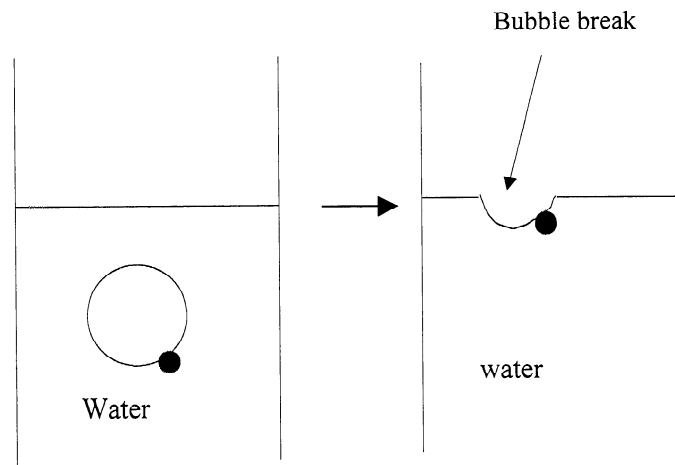


Figure 2. Ink adheres to an air bubble in the absence of surfactant. The bubble breaks when it moves to the surface. As a result, no foam can be generated and the ink particle will return to the bulk phase.

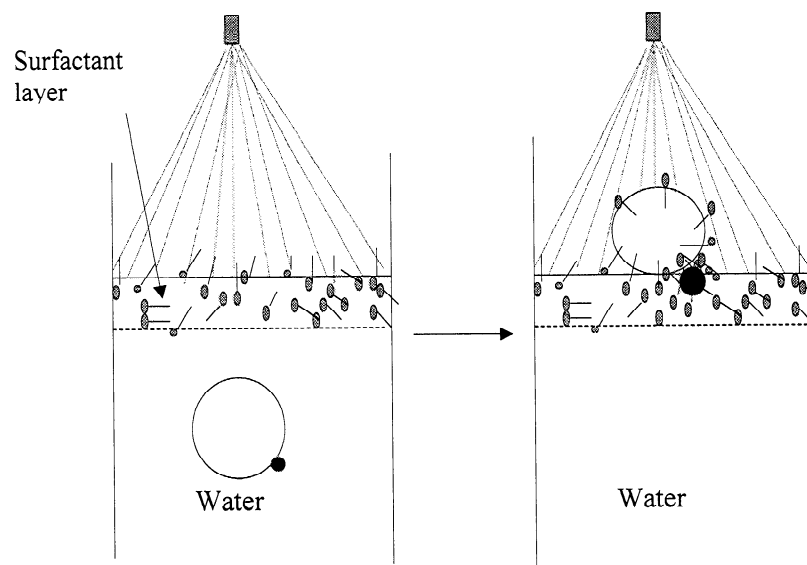


Figure 3. Surfactant spray creates a surfactant layer on the top of the flotation cell. When an air bubble passes through this layer, the surfactant adsorbs onto the bubble surface. As a result, the bubble can be stabilized and a foam layer can be generated. The ink particle can therefore, be transferred to the foam layer as in a conventional flotation process.

The experimental results conducted at IPST using a laboratory batch-type deinking column is shown in Fig. 4. Xerox copied bond papers printed with a fixed pattern were used in this study. It was found that a stable foam layer could be established on the surface of pulp slurry by spray surfactant in less than 0.5 minutes. The rate of foam formation on the top of pure water depends on the spray rate and surfactant concentration of the spray solution, and usually a few seconds are needed to generate a constant froth height.

Direct sampling measurements of the surfactant concentration distribution within the flotation column as a function of spray time and depth from froth/suspension interface showed that surfactant was mainly concentrated in the froth rather than in the pulp slurry.

Figure 4 also compares the results obtained from surfactant spray flotation and conventional flotation under the same operational conditions. The results clearly show that the surfactant consumption used in the surfactant spray flotation is only about 2-3% of that required for a conventional flotation process in order to achieve the same brightness gain. This is not surprising because the surfactant is applied directly to the froth phase to stabilize the foam in the surfactant spray flotation, but most surfactants dissolved in pulp in a conventional flotation process will not contribute to froth stabilization. Theoretically, the surfactant consumption used in the spray flotation process can be further decreased if the ratio of the height of the flotation column to the surface area is increased because the surfactant consumption in spraying flotation does not depend on the total volume, but depends only on the total surface area of the pulp suspension.

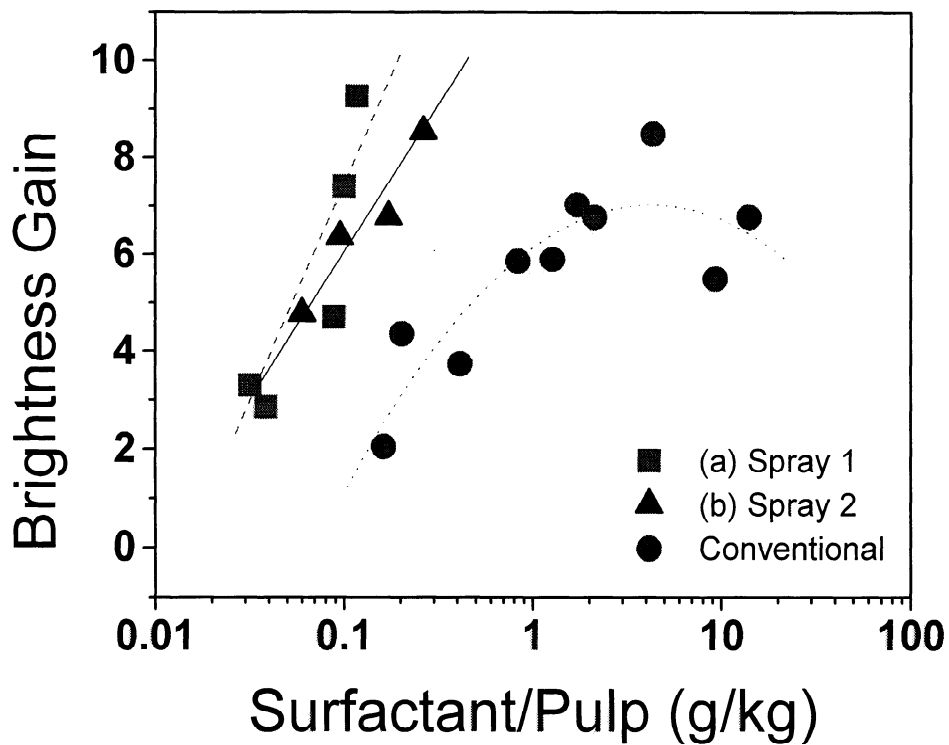


Figure 4. The brightness of handsheets as a function of surfactant consumption. The surfactant concentrations in the spray solutions were 16 and 40 mg/L for Spray 1 and Spray 2, respectively. For surfactant spray, the total surfactant consumption was made by varying the flotation time. In the conventional flotation tests, 10-min flotation time was used.

Figure 4 also shows that the deinking efficiency increases as the surfactant concentration initially increases, then decreases with further increases in surfactant concentration. It is believed that the increase in the deinking efficiency at low surfactant concentration is because of the increase in the froth stability, and the decrease in deinking efficiency at high surfactant concentration is because of the decrease in the hydrophobicity of ink particle surfaces. Because there is an optimum surfactant concentration in conventional flotation

deinking, it is often difficult to control surfactant concentration in industrial applications as it often changes with fiber sources. In contrast to the conventional flotation method, it is not necessary to find an optimum surfactant concentration if the surfactant is added from the top of the flotation cell as indicated by the data shown in Fig. 4.

In addition to the improvement in the ink removal efficiency, it was also noted from our laboratory study that under the same conditions, the surfactant spray approach could reduce fiber loss by 50%, water loss by 75%, and surfactant consumption by 95%.

The surfactant spray technique has been recently scaled up using small pilot flotation equipment built at IPST. In general, the pilot results are positive. Several paper mills have also been involved in a collaborative research project to develop surfactant spray technique. IPST is also looking for further funding from DOE and the industry to continue this project.

